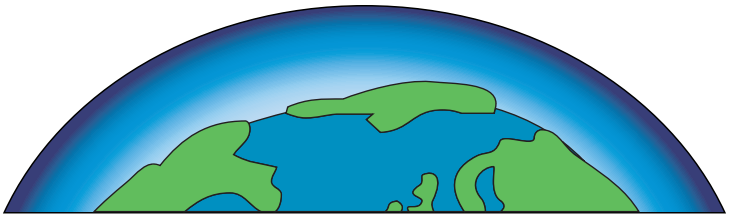


Lesson 3: Greenhouse Gases: Carbon Dioxide and Water Vapor

Students explore the unique properties of greenhouse gases, which allow these gases to influence the surface temperature of a planet.

Main Lesson Concept: Carbon dioxide and water vapor are greenhouse gases that absorb energy radiated from Earth's surface and release some of it back towards the Earth, increasing the surface temperature.

Scientific Question: What are greenhouse gases? How do the unique properties of greenhouse gases affect a planet and human life?

Objectives	Standards
• Students will identify CO_2 and H_2O as greenhouse gases and explain that these gases absorb energy radiated from Earth's surface and release some of it back towards the Earth, surface increasing the surface temperature.	**Partially meets**: 2061: 4E (6-8) #3 **Addresses:** NSES: B (5-8) #3.1 NSES: B (5-8) #3.2 NCTM: 5, 9

Assessment	Abstract of Lesson
Responses to Astro Journal final questions.	Students engage in a radiating heat activity and an activity that measures temperature in models with and without greenhouse gases. They draw conclusions about the effect of greenhouse gases on temperature and on human life. They will also kinesthetically model the absorbing and reradiation of heat.

Prerequisite Concepts	Major Concepts
• Earth's atmosphere absorbs heat, which increases and sustains the temperature of the planet. (Astronomy Lesson 10) • The atoms of any element are alike but are different from atoms of other elements. Atoms may stick together in well-defined molecules. (Atmosphere Lesson 2) • Humans need a stable, moderate temperature for survival. (Astronomy Lesson 1) • Humans need carbon dioxide and water vapor in certain quantities. (Atmosphere Lesson 1) • An increase in temperature causes molecules to vibrate more quickly. (Astronomy Lesson 5) • To radiate is to send energy traveling in all directions through space.	• Heat can be transferred across space by radiation. • Carbon dioxide and water vapor are greenhouse gases. • Greenhouse gases absorb heat that radiates from Earth's surface and release some of it back towards the Earth, increasing the surface temperature. • Greenhouse gases benefit humans by maintaining a stable, moderate temperature. • A substantial increase in greenhouse gases could harm human life.

Suggested Timeline (45-minute periods):
Day 1: Engage and Explore Day 1 Sections
Day 2: Explore Day 2 Section
Day 3: Explain and Extend Sections
Day 4: Evaluate Section (20 minutes)

Materials and Equipment:

- A class set of Astro Journal Lesson 3
- A class set of Planet Temperature/Atmosphere Chart
- Signs or name tags for each student to indicate the element they represent

Radiating Heat and Greenhouse Modeling Activities (each group will need the following):

- 2 lamps with 200 watt bulbs
- 2 terrariums or large glass jars
- 2 thermometers
- Cardboard to make 2 thermometer stands (optional)
- Plastic wrap
- Watch or a clock with a second hand
- Dark potting soil (for 2-3 cm layers in each jar)
- One spray bottle filled with water (this could be shared amongst groups)
- Ruler or tape measure
- Spreadsheet/graphing software (optional)
- Temperature probe and data collection device such as a P.D.A. (optional)

Preparation:

- Gather materials.
- Duplicate Astro Journal, and Planet Temperature/Atmosphere Chart.
- Prepare classroom. Make sure there's room for the Kinesthetic Greenhouse Gases Activity in the Extend section.
- Prepare chart paper with the major concept of the lesson to post at the end of the lesson.

Differentiation:

Accommodations

For students who may have special needs:

- Have them work with a partner on the Astro Journal writing or report orally to the teacher.

Advanced Extensions

For students who have mastered this concept:

- Research and report on global warming. Is it happening? How are people responding to it? What other gases are greenhouse gases? What is causing an increase in carbon dioxide levels? What new technologies can help decrease carbon dioxide levels?
- Give students a more open-ended version of the greenhouse modeling activity by providing a variety of different materials and having students design and test different models. Have them draw conclusions about which results in the best model of how the greenhouse effect works.

Engage (approximately 15 minutes)

1. **Draw on student's prior knowledge or experience with atmosphere's role in affecting Earth's surface temperature.**
   - Question: Imagine it is winter, and you have been having sunny, clear days. Now, one morning you wake up, and look out the window to see that it is very cloudy. How do you think the temperature outside will compare to yesterday's?
   - *Answer: It will probably be warmer outside.*
   - Question: Have you had an experience like this before? What have you observed?
   - *Answers may include: It seems like in the winter, whenever it is clear it is colder, and when its cloudy it gets warmer.*

2. **Review the role of Atmosphere in a planet's temperature (Astronomy Lesson 10) and the properties and characteristics of molecules (Atmosphere Lesson 2).**
   - Question: What three factors did we learn in Astronomy determine the surface temperature of a planet?
   - *Answer: We learned that a star's type, a planet's distance from its star and the amount and composition of its atmosphere all work together to determine the surface temperature of a planet.*
   - Question: How does Earth's atmosphere affect the planet's temperature?
   - *Answer: The atmosphere absorbs heat.*
   - Question: Do all of the gases in our atmosphere absorb heat?
   - *Answer: (Allow students to discuss their ideas. Don't provide the answer at this time.)*
   - Question: What have we learned about the properties and characteristics of atoms?
   - *Answer: The atoms of any element are alike but are different from atoms of other elements.*
   - Question: What have we learned about molecules?
   - *Answer: Molecules are made up of atoms.*
   - Question: Do molecules behave the same way as the atoms that make them up when not in a molecule? Why do you think that?
   - *Answer: (Allow students to discuss their ideas about this. Encourage them to use the metaphor of building materials and constructions to support their answer.) Just as our constructions did not have the same properties and characteristics as the individual building materials that they were made of, molecules do not behave the same as the individual atoms that make them up.*
   - Question: Do molecules behave the same way as different molecules? Why do you think that?
   - *Answer: (Allow students to discuss their ideas about this. Encourage them to use the metaphor of building materials and constructions to support their answer.) A construction that was made of blocks and fabric would not have the same characteristics as a construction made of fabric and rubber bands, so different molecules probably behave differently.*

3. Bridge to this lesson and introduce the purpose and Scientific Question.

- Say: Every gas in our atmosphere is unique and different from other gases. Today, we are going to learn about some of the gases that have the unique ability to absorb heat, playing a role in determining the surface temperature of our planet and, thus in supporting human survival. These gases are called greenhouse gases.
- Say: The Scientific Questions we will be exploring are:
  - What are greenhouse gases?
  - How do the unique properties of greenhouse gases affect a planet and human life?

Explore — Day 1 - (approximately 30 minutes)

1. Guide students in the Radiating Light and Heat Activity.

- Question: What is the relationship between light and heat?
- *Answer: Things that are hot sometimes give off light. Things under a light source sometimes heat up.*
- Put students into small groups. Give groups light sources and have them use their hands as the object to be heated by the light.

  Note to Teacher: Be sure to caution students not to touch the light bulb while it is on or right after it has been turned off, as they could burn themselves.
- Have students predict in their Astro Journals: What will happen to your hand if you shine a strong light source on it for a period of time?
- Students test their hypotheses with the light source and record their observations.
- Have students predict in their Astro Journals: Could the heat from your hand be transferred to your cheek even if your hand didn't touch your cheek?
- Have groups heat up one student's hand with the light and test for heat radiation with their cheeks (students should not touch the hand to their cheek). Students record their observations in their Astro Journals.
- Question: Think of the light source as the Sun, and your hand as Earth. Based on your observations, what happens when the heat from the Sun reaches Earth?
- *Answer: Earth heats up and begins to radiate heat.*
- Finish Astro Journal: Describe what happens when heat from the Sun reaches Earth.

Explore — Day 2 - (approximately 45 minutes)

1. Lead students in the Greenhouse Modeling Activity.

- Have students predict in their Astro Journals: How will the temperature of a planet with greenhouse gases compare to one without?
- Discuss the Greenhouse Modeling Activity.
  - Tell students that the experiment they will be conducting is a model of how greenhouse gases work. They will have one terrarium or glass jar that is a model of a planet without greenhouse gases, and one that is a model of a planet with greenhouse gases. Ask them to pay attention to the parts of the experiment and what each part represents.

Note to Teacher: It is important to stress that greenhouse gases do not hold heat in like plastic wrap, but both result in increased temperatures. Ideally you would do this experiment by having more of a greenhouse gas such as CO_2 in one jar, but not the other. However, you would not see much difference between the two models, because this really only works on a larger scale.

This was carefully tested by teachers at the National Center for Atmospheric Research who tried increasing CO_2 using matches, dry ice, vinegar, baking soda and CO_2 cartridges, but could not produce consistent results.

Greenhouse gases absorb and reradiate heat, but plastic wrap just traps heat. Bring this out with the following discussion.

- Question: What are we using to represent the grenhouse gases in this experiment?
- *Answer: The plastic wrap represents the greenhouse gases.*

- Question: How are greenhouse gases different from plastic wrap?
- *Answer: Greenhouse gases are not a plastic cover surrounding the earth. They are gases in our atmosphere.*

- Say: This is a very important difference. As you conduct your experiment, it's important to observe how plastic wrap behaves differently than greenhouse gases. Think about how plastic wrap is like greenhouse gases and how it is different from greenhouse gases.

  - Discuss with students the importance of making sure that both models are exactly the same except for the "variable" you want to focus on. In this case, the variable is the greenhouse gases symbolized by the saran wrap. Discuss what might happen if there were other differences between the two terrariums, such as different amounts of soil or different distances of the two lamps and how these differences can make it hard to determine whether the changes observed are attributed to the variable of interest or to other factors.

- Go over the Greenhouse Modeling Activity.
  - Cover the bottom of two terrariums or glass jars with 2-3 centimeters of dark soil.
  - Place a thermometer inside each terrarium. You might consider using thermometer stands that can be made from cardboard so that the thermometers are raised above the soil and allow you to easily read the numbers.
  - Lightly dampen the soil with a spray of water from the spray bottle.
  - Cover one terrarium or glass jar with plastic wrap.
  - Locate a lamp approximately 25 centimeters above the center of the top of each box.
  - Record the temperature of the thermometers on the data charts.
  - Record the temperature of each terrarium or jar every minute for 15 minutes.
  - Turn the light off for fifteen minutes. Again record the data on your data table every minute for 15 minutes.
  - Graph both sets of data.
  - Respond to the questions.

Note to Teacher: The graphing units are not provided so that students can go through the process of thinking out how best to graph their results. Suggested units are to use minutes for the x-axis, and temperature in degrees Celsius for the y-axis. Help students to decide on these units by asking such questions as, "What kind of graph will show us a change over time?" "What units will we want to use across the bottom to see this change?" "What units should we use along the side to help us see what is changing over time?"

Consider integrating the use of technology by having students use a spreadsheet/graphing software program to graph their results. Another technology tool that could be used here is a temperature probe connected to a data collection tool such as a personal digital assistant (P.D.A.)

- Have students conduct the Greenhouse Modeling Activity.
- Have students record their findings in their Astro Journals.

Explain (approximately 10 minutes)

1. **Discuss with students their conclusions from the Radiating Heat Activity.**
   - Question: What were your results of the Radiating Heat Activity? Could the heat from your hand be transferred to someone's cheek without touching?
   - *Answer: Yes.*
   - Question: How was this heat transferred, if you didn't touch each other?
   - *Answer: It was transferred across space by radiation. Heat radiated from hand to cheek, just like the Sun's heat radiates to Earth.*
   - Question: What can you conclude happens when heat from the Sun reaches Earth?
   - *Answer: Heat radiates from the Sun to Earth and then radiates from the Earth back to the atmosphere raising the temperature of the atmosphere.*
2. **Discuss with students their conclusions from the Greenhouse Modeling Activity.**
   - Question: What was the difference between the graph of the model with plastic wrap and the one without plastic wrap?
   - *Answer: The temperature of the model with plastic wrap rose more quickly but did not drop as quickly as the model without plastic wrap.*
   - Question: Why did this happen?
   - *Answer: The heat bounces off the dark ground and instead of going outside of the model, the plastic wrap traps it. This causes the temperature to go up more quickly. When the light is turned off, the heat in the model without saran wrap can escape more quickly then the heat in the model with saran wrap, so the temperature decreases more quickly in the model without saran wrap.*
   - Question: What does this tell you about how greenhouse gases affect temperature?
   - *Answer: Greenhouse gases reradiate some heat back to the source, thus causing the temperature to be higher than it otherwise would be.*

MISCONCEPTION: A commonly held misconception about greenhouse gases is that they 'reflect' heat back to the Earth. Greenhouse gases do not 'reflect' heat. They retain or absorb heat that radiates off of the Earth's surface and reradiate it back to Earth and to space. Most of the heat, in fact, returns back to space. Students may also conclude that the gases absorb heat when sunlight first penetrates the atmosphere from the Sun, but this is not the case except for some like ozone, which has some absorption in the ultraviolet and in the infrared wavelengths . The Earth first absorbs the visible radiation from the Sun, which is then converted to heat, and this heat radiates out to the atmosphere, where the greenhouse gases then absorb some of the heat. Be sure to check for student understanding of these concepts. The Kinesthetic Greenhouse Gases Activity at the end of the lesson, will help to reinforce the actual process.

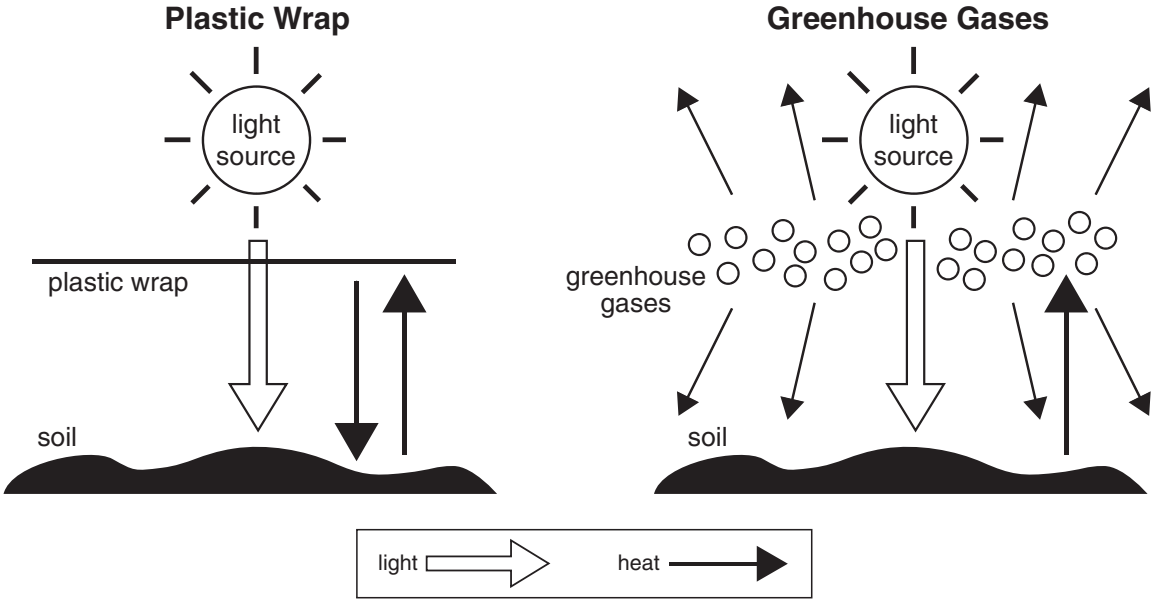
- Question: Which gases in our atmosphere are greenhouse gases?
- *Answer: Carbon dioxide, water vapor and methane.*

- Question: If this is a model of a planet with and without greenhouse gases, What does each part represent?
- *Answer: The light represents the Sun or a star. The soil represents the land on the planet. The air in the box, represents the atmosphere of the planet, and the plastic wrap represents the greenhouse gases.*

- Question: How was this a realistic model of the greenhouse effect?
- *Answer: The model is realistic, because it shows how greenhouse gases capture the heat radiated from the Earth's surface and how they affect the temperature of the planet.*

- Question: How was this NOT a realistic model of the greenhouse effect?
- *Answer: The model is not realistic, because greenhouse gases are not exactly like plastic wrap; they actually absorb and reradiate heat rather than just trapping heat.*

- To emphasize this difference, ask students to illustrate the difference between greenhouse gases and plastic wrap by drawing arrows that represent heat. The illustrations should show that plastic wrap reflects most heat straight back to the Earth, while greenhouse gases radiate heat in all directions.



Extend/Apply (approximately 35 minutes)

MISCONCEPTION: Many people believe that the Greenhouse Effect is dangerous for life on Earth. However, if it were not for the Greenhouse Effect, the temperature on Earth would be too cold for human survival. The following discussion is very important in helping students to understand this.

1. Discuss with students how greenhouse gases benefit life on Earth.

- Hand out or post the Planet Temperature/Atmosphere Chart.

- Have students look at these terrestrial planets and our moon and observe patterns concerning the amount of greenhouse gases compared to each planet's temperature range. Have students put the planets and our moon in order from smallest temperature range to largest temperature range: (Venus, Earth, Mars, Moon, Mercury).

- Question: What do you notice about the differences in the temperature ranges of these planets and how they compare to the amount of greenhouse gases each has?
- *Answer: The more greenhouse gases a planet has, the smaller the temperature range. Venus has so much carbon dioxide that its temperature doesn't really change at all, whereas the moon and Mercury have very wide temperature changes.*

  Note to Teacher: Be sure to discuss with students that one factor that varies with each planet is the distance from the Sun, which also plays a role in determining the surface temperature of a planet. This especially affects Mercury and Mars. Also be sure to help students to understand that even though the percentage of CO_2 on Mars is a high percentage of Mars' atmosphere, Mars has very little atmosphere in total. Mars has only 0.0061 bar of atmosphere compared to 1 bar on Earth.

- Question: So what happens to the surface temperatures of planets and moons that do not have greenhouse gases in their atmospheres?
- *Answer: At nighttime, they become very cold, because there are no greenhouse gases to absorb the heat and keep them warm when they are not facing the Sun.*

  Note to Teacher: You may want to point out to students that greenhouse gases are an important component in maintaining the right temperature, but other factors also play a role. In fact, some scientists theorize that our ocean currents might play a big role in transferring heat and preventing an ice age.

- Question: What benefit do greenhouse gases give to life on Earth, especially humans? What would happen if we didn't have greenhouse gases?
- *Answer: If we didn't have greenhouse gases: the temperature on Earth would be colder; the night to day temperature differences would be large; and humans could not survive.*

  Note to Teacher: Scientists theorize that the Earth would be 30 to 40 degrees cooler without the Greenhouse Effect.

2. Discuss with students how increasing greenhouse gases might harm life on Earth?

- Question: What would happen if the greenhouse gases on Earth increased?
- *Answer: Surface temperatures and lower atmospheric temperatures would increase.*

  Note to Teacher: It's important to note that the surface temperatures and lower atmospheric temperatures would increase the most, whereas the upper atmosphere can cool. This has important implications for the formation of ozone, which forms under cooler conditions.

- Question: How might this affect human life on Earth?
- *Answer: If temperatures increased too much, humans might not be able to survive.*

  Note to Teacher: Increasing CO_2 will cause an increase in temperature, which will in turn cause more water vapor to evaporate. Since water vapor is a greenhouse gas, this will cause the temperature to increase even more. Scientists agree that the temperature will increase, but they do not agree by how much and what the results of an increase in temperature might be. This is because the Earth system is so complex. Some scientists believe that increasing temperature may result in increased cloud cover, which will actually result in less sunlight reaching the Earth's surface, stabilizing the temperature or even lowering it. Some scientists observe that historically, an increase in global temperature may have resulted in an ice age, since the salinity of the ocean decreased, disrupting ocean currents that transfer heat from warmer climates to cooler climates.

It is also important to note that Earth's temperature has fluctuated throughout Earth's history. These fluctuations have occurred over long and short time scales ranging from thousands of years to millions or billions of years. This has caused periods of increased temperatures, such as during the Mesozoic period (225 million to 65 million years ago) when dinosaurs roamed the Earth, or periods of decreased temperatures, such as the ice ages. These changes can occur not only with a change in composition of the atmosphere but also due to other factors such as the luminosity of the Sun or the eccentricity of Earth's orbit. As is seen in the Astro-Venture Astronomy unit, the planetary temperature system is a complex system.

- You may want to have students research how humans can increase greenhouse gases in the atmosphere, what the current levels are, and how this compares with past levels.

3. Facilitate the Kinesthetic Greenhouse Gases Activity.

- Explain to students that they will be physically modeling greenhouse gases and radiation of heat.
- Have students model the gases that compose the atmosphere as they did in the Extend Day 2 section of Atmosphere Lesson 2. Make sure that you have at least one molecule of each gas: H_2, O_2, N_2, H_2O and CO_2. Have students wear a sign or name tag that indicates the element they represent.
- Have a group of three students link arms to represent heat and another student represent the Sun. Have a wall that is across from the Sun, represent Earth. Have the student molecules spread out between the Sun and the Earth.
- Have the students who represent heat start close to the Sun, leave the Sun and travel to the Earth. They should travel uninhibited to the Earth, going under the arms of the bonded molecules or around the molecules.
- Once the students representing heat reach the Earth, they should "bounce" off and travel back toward the Sun. On their way back, if they encounter CO_2 or H_2O, they should touch the molecule, which begins to vibrate more quickly and then sends one of the students "bouncing" back toward Earth again. The other two students representing heat should continue on their journey back out to space. If they encounter H_2, O_2 or N_2 they should travel under the arms of the bonds or around these molecules.

MISCONCEPTION: A common misconception that may confuse students is that clouds are water vapor. Given this misconception, they may observe that clouds block sunlight and assume that the heat from the sun should be bounced back from the water molecule out to space. Clouds are actually condensed water, which is different from water vapor. Make sure that the water molecule is clearly labeled: water vapor, and if necessary explain this distinction to students.

- In their Astro Journals, have students draw and explain greenhouse gases' role in the surface temperature of a planet and the subsequent effect on human life.

Evaluate (approximately 20 minutes)

1. Discuss students' responses in their Astro Journals to ensure they have mastered the major concepts.

- Question: What role do greenhouse gases like carbon dioxide and water vapor play in the temperature of the Earth's surface?
- *Answer: Greenhouse gases like carbon dioxide and water vapor absorb heat that is radiated from Earth's surface and release some of the heat back towards the Earth, increasing the surface temperature.*

- Question: How does this affect human life on Earth?
- *Answer: By absorbing heat, greenhouse gases help to maintain a stable temperature for human survival. Without enough greenhouse gases, it would be too cold for human survival. With high levels of greenhouse gases, it might be too warm or cause other disruptions in the Earth's system that could jeopardize human survival.*

- Question: Do all gases absorb heat?
- *Answer: No. Only some gases have the unique property of being able to absorb heat.*

2. Collect students' Astro Journals and evaluate them to ensure that they have each mastered the major concepts:

- Carbon dioxide and water vapor are greenhouse gases that absorb energy radiated from Earth's surface and release some of it back towards the Earth, increasing the surface temperature.

- This helps to maintain a stable temperature necessary for human survival.

3. Bridge to next lesson.

- Today we learned about the unique properties that carbon dioxide and water vapor have and how those unique properties are important to human survival. In the next lesson we'll learn how molecules can change or transform.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the "conceptual flow" and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Astro Journal Atmosphere Lesson 3:
Greenhouse Gases Radiating Light and Heat Activity

Name:

Class/Period:

Date:

1. Prediction: What will happen to your hand if you shine a strong light source on it for a period of time?

2. Summarize your observations of the Radiation Activity.

3. Prediction: Could the heat from your hand be transferred to your cheek even if your hand was not touching your cheek?

4. Describe what happens when heat from the Sun reaches Earth. Draw a picture of what happens to the

Greenhouse Modeling

Procedure:

1. Cover the bottom of two terrariums or glass jars with 2-3 centimeters of dark soil.
2. Place a thermometer inside each terrarium. You might consider using thermometer stands that can be made from cardboard so that the thermometers are raised above the soil and allow you to easily read the numbers.
3. Lightly dampen the soil with a spray of water from the spray bottle.
4. Cover one terrarium or glass jar with plastic wrap.
5. Locate a lamp approximately 25 centimeters above the center of the top of each box.
6. Record the temperature of the thermometers on the data charts.
7. Record the temperature of each terrarium or jar every minute for 15 minutes.
8. Turn the light off for fifteen minutes. Again record the data on your data table every minute for 15 minutes.
9. Graph both sets of data.
10. Respond to the questions.

1. Prediction: How will the temperature of a planet with greenhouse gases compare to one without?

Name:

Class/Period:

Date:

Greenhouse Gases Radiating Light and Heat Activity

2. Greenhouse Modeling Data Chart

Model Without Plastic Wrap
Original Temperature:

Light On		Light Off	
Minute	Temperature	Minute	Temperature

Model With Plastic Wrap
Original Temperature:

Light On		Light Off	
Minute	Temperature	Minute	Temperature

Astro Journal Atmosphere Lesson 3:
Greenhouse Gases CO_2 and H_2O

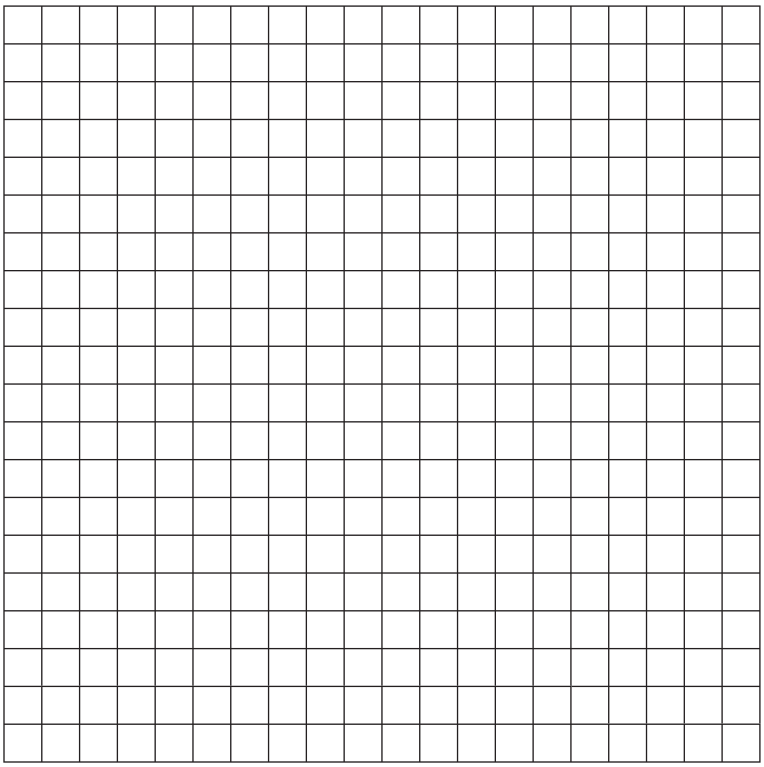
Class/Period:

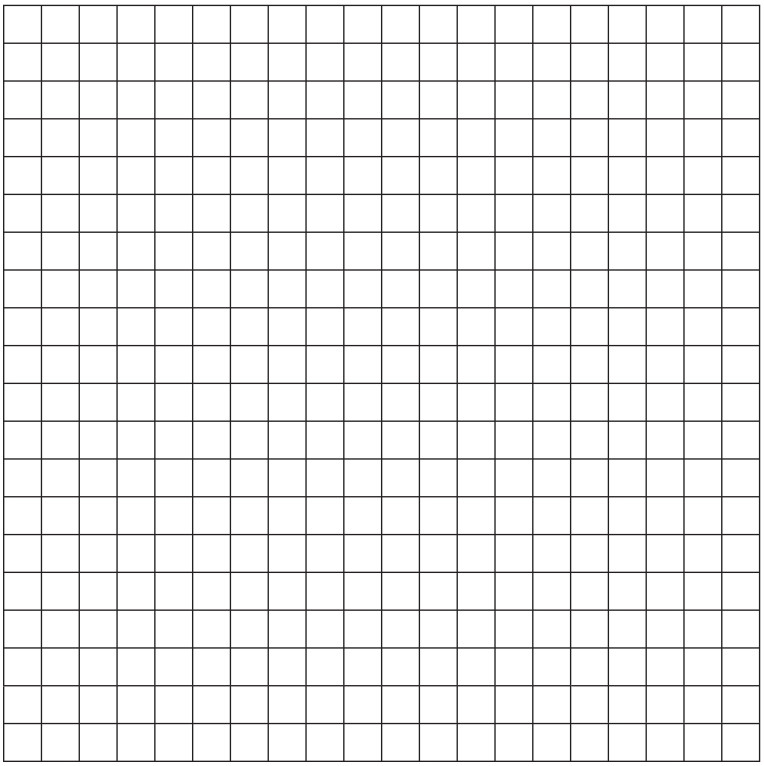
Name:

Date:

Greenhouse Gases Radiating Light and Heat Activity

3. Graph both sets of data below.





Astro Journal Atmosphere Lesson 3:
Greenhouse Gases CO_2 and H_20

Name:

Class/Period:

Date:

CO_2 and Heat Activity Questions

1. What is the difference between the two graphs? Why?

2. What do the graphs tell us about how greenhouse gases affect temperature?

3. The models simulate a planet with greenhouse gases and without greenhouse gases. What does each part represent? (lamp light, soil, air in the box, and the plastic wrap)

4. How was this a realistic model of the greenhouse effect?

5. How was this NOT a realistic model of the greenhouse effect?

Name:

Class/Period:

Date:

Modeling CO_2 and Carbon Activity

1. Draw a picture of how CO_2 and other greenhouse gases affect temperature. Explain your drawing.

2. What effect do greenhouse gases have on life on Earth? Explain.

Planet Temperature/Atmosphere Chart

Planet	Temperature Range	Amount of Atmosphere	Atmospheric Composition
Mercury	-170° C to 662° C (520° difference)	Trace atmosphere = ~0.000000000000010 bars*	42% oxygen (O_2) 29% sodium (Na), 22% hydrogen (H_2) 6% helium (He) 0.5% potassium (K), possible trace amounts of: argon (Ar), carbon dioxide (CO_2), water (H_2O), nitrogen (N_2), xenon (Xe), krypton (Kr), neon (Ne)
Venus	constant 465° C (0 to 10° difference)	Atmosphere = 92 bars	96.5% carbon dioxide (CO_2) 3.5% nitrogen (N_2) 0.0020% water (H_2O) trace amounts of: sulfur dioxide (SO_2), argon (Ar), carbon monoxide (CO), helium (He) and neon (Ne)
Earth	-50° C to 45° C (59° difference)	1 bar (at sea level)	78% nitrogen (N_2) 21% oxygen (O_2) 0.035% carbon dioxide (CO_2) 1 to 4% water vapor (H_2O) 300 Dobson Units ozone (O_3) 0.002% methane (CH_4) 0.9% argon (Ar) trace amounts of: helium (He), krypton (Kr) and hydrogen (H_2)
Moon	-153° C to 134° C (287° difference)	0 bars	no atmosphere
Mars	-111° C to 26% C (137° difference)	Atmosphere = 0.0061 bars	95.32% carbon dioxide (CO_2) 2.7% nitrogen (N_2) 1.6% argon (Ar) 0.13% oxygen (O_2) 0.08% carbon monoxide (CO) water (H_2O) – 0.0210%; trace amounts of: nitrogen oxide (NO), neon (Ne), hydrogen-deuterium-oxygen (HDO), krypton (Kr) and xenon (Xe)

* 1 bar is the average atmospheric pressure at sea level on Earth.